PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Cavity Resonator Type Electron Tube Apparatus

We, EITEL-MCCULLOUGH, INC., a corporation organized under the laws of the State of California, United States of America, and having a place of business at San Bruno, San Mateo County, California, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to cavity resonator type electron tube apparatus and more particularly to cavity resonators therefor having improved tuning means.

It is well known in the art that the frequency of a cavity resonator can be varied by changing the volume of the cavity. Further, in U.S.A. patent No. 2,619,611, it has been disclosed that a cavity resonator can be formed with an evacuated, vacuum-tight portion and another portion external to the evacuated portion. A wall section of the evacuated portion is made of ceramic or other dielectric material which permits radio-frequency energy to pass therethrough into the external portion. In this manner the two portions co-operate to form in effect a composite cavity resonator. The advantage of this composite type of cavity is that the means for adjusting its volume can be located entirely in the external portion, thereby avoiding the complicated sealing arrangement which is required in order to vary the volume of an evacuated chamber.

In cavity resonators of the type used in klystrons the dielectric section of the evacuated portion is normally formed in the shape of a cylinder and the external cavity portion is formed in the shape of a split rectangular box fitted symmetrically around the dielectric cylinder. In prior disclosures such as U.S.A. patent, No. 2,619,611, the rectangular box is provided at each end with a flat partition, or tuning door, which is movable toward and away from the dielectric cylinder to adjust the volume of the cavity resonator.

The main object of the present invention is to provide improved tunable cavity resonator structure capable of producing a higher resonant frequency for a given size cavity than was heretofore possible.

With this object in view the present invention provides, in electron discharge apparatus, a composite cavity resonator comprising a vacuum-tight internal portion and a portion external thereto, said portions being divided one from the other by a cylindrical wall section of dielectric material, a tuning door in said external portion and movable towards and away from said wall section, said tuning door comprising a contact rim making, over the entire periphery of the door, sliding contact with the inside of the external portion which contact serves to define the electrically effective volume of the resonator and takes place along an endless line which lies substantially in one plane and a body portion of said door extending from said rim toward said cylindrical wall section and spaced from the inside of said external portion, the surface of said body portion which faces said cylindrical wall section being (in transverse cross-section) concave towards the axis of said section and adapted to partially surround said wall section.

One embodiment of the invention will now be described by way of example with reference to the accompanying drawings, in which:—

Figure 1 is an axial sectional view of a 3-cavity klystron incorporating the improved tuning arrangement of the invention. The external portion of the middle cavity is removed to show more clearly the extent of the inner or evacuated portion.

Figure 2 is essentially a side elevational view of the input tuning box taken on the plane of line 2 in Figure 1.

Figure 3 is a front elevational view of the tuning box assembled separate from the klystron.

Figure 4 is a sectional view on an enlarged scale taken on the plane of line 4 in Figure 1 and showing one half section of a tuning box in assembled position on the klystron; and

Figure 5 is an enlarged sectional view of the input coupling taken on the line 5—5 of

Figure 3.

Referring in more detail to the drawings, Figure 1 shows a beam type tube known as a klystron. The tube comprises an elongated evacuated envelope having an electron gun 6 at one end and a collector electrode 7 at the other end. The collector electrode is separated from the electron gun by a drift tube having a plurality of spaced tube sections 9, 10, 11 and 12 forming gaps 13, 14 and 15 therebetween. The drift tube sections are preferably made of copper, and, in order to insulate the collector from the drift tube, a ceramic cylinder 16 is employed between the last tube segment 12 and collector 7 which is also preferably made of copper.

Electron gun 6 comprises a cathode 17 housed in a cup-shaped anode 18 preferably made of copper. The anode is connected to the first drift tube segment 9, and electrons from the cathode are focussed into the drift tube by a cylindrical focusing electrode 19. The entire gun structure is mounted on a suitable stem 20 which may be of conventional glass and metal construction with suitable terminals for the various electrodes. Collector electrode 7 at the opposite end of the tube is simply a cup-shaped structure which may be provided with suitable exhaust tubulation 22 and cooling structure not shown.

The separate drift tube sections are joined in the following manner to form internal resonator portions 24 adjacent the gaps 13, 14 and 15. The three internal resonator portions are identical, and therefore particular reference is made to the second or intermediate resonator structure which provides the clearest disclosure. Circular end plates 25 of metal such as copper are brazed on the drift tube sections adjacent the gaps 13, 14 and 15. A cylindrical envelope section or window 26 of dielectric material such as ceramic is positioned between the end plates 25 and connected thereto by means of the conventional sealing flange structures 27.

The structure thus far described is conventional and presents a vacuum-tight envelope which forms the tube per se. It will be noted that the cavity resonator portions 24 are not adjustable in size and therefore do not per se provide variable frequency. In order to provide tuning means and increase the volume of the cavity, external cavity resonator portions or tuning boxes 30 are positioned externally of the tube envelope.

In Figure 1 it will be noted that no tuning box is shown in connection with the second cavity. This is done to disclose more clearly the appearance of the vacuum envelope of the tube before the external tuning boxes are attached. However, it should be understood that when the tube is operated, the second cavity will be equipped with a tuning box 30 in the manner shown for the first and third cavities.

Referring now to Figures 1—4, it will be seen that each of the external tuning boxes is made in two halves. Each half comprises a rectangular box having narrow sides 31 and wide sides 32. In respect to each internal cavity portion 24, a tuning box 30 is attached by placing the two halves of the box on diametrically opposite sides of the cavity and clamping the halves together to complete the cavity externally of the vacuum envelope. Any suitable clamping means can be employed to join the two halves of the boxes. For example, the halves can be bolted together, or the quick acting means shown in the drawings can be used. Such means consist of the conventional latches 34 cooperating with the hooks 35, the latches being mounted on opposite box halves from the hooks.

The physical contact between the tuning box halves and the evacuated portions of cavity resonators 24 will now be described. The wide sides 32 of each box half are provided with semicircular recesses at their inner ends, and a semicircular flange 36 is brazed along the rim of each recess. A semicircular metal strip 37 is attached to each flange 36 by means of screws 38, and a plurality of resilient metal contact fingers 39 having one end clamped between flange 36 and ring 37 and projecting inwardly of the tuning box are disposed along the periphery of the recesses. Such contact fingers 39 are conveniently provided by cutting slots part way across a resilient metal strip and clamping the uncut portion of the latter strip between the flange 36 and the strip 37 with the digitate portion projecting therefrom. The size and shape of the semicircular parts is such that when the tuning box halves are clamped together the contact fingers 39 are pressed into good electrical contact with the outer rims of end plates 25 of the evacuated cavity portion.

The tuning boxes 30 when clamped to the evacuated cavity portions serve to provide cavity resonators which have a given lower resonant frequency in the TE_{101} mode, but would not alone provide any means for varying such frequency in operation to accomplish tuning. Accordingly, the electrically effective outer ends of the tuning boxes 20 are made radially adjustable relative to the tube axis. Such electrically effective outer ends are designated generally 41 and are called tuning doors.

As shown best in Figure 4, each of the tuning doors comprises a body portion 42 preferably in the form of a hollow casting to lighten the structure. A particularly important features of door 41 is that the lower or inner surface of this body portion 42 has a concave shape as will be described in greater detail hereinafter. The internal wall surface of body portion 42 is provided with a plurality of ribs 43 which are tapped to accommodate screws 44. A cover plate 45 is attached by means of screws 44, and two metal strips are clamped between cover plate 45 and the body portion 42 to provide a contact rim comprising inner and outer contact fingers 46 and 46^1, respectively. In order to

provide means for moving doors 41 in and out along the tuning boxes, a threaded drive shaft 47 is attached to each of the doors. The lower end of each shaft 47 is provided with a flange 48 which rests against the solid center part of body portion 42. A split collar 49 is attached on top of cover plate 45 by means of screws 50 and extends into a recess on drive shaft 47 which is above flange 48. In this manner the drive shaft is permitted to rotate relative to the tuning door 41 but is not permitted to move axially relative to the door. A plate 51 is mounted in the outer end of each tuning box half by means of screws 52. Plate 51 is thus provided with an apertured center boss 53 which is internally threaded to receive drive shaft 47. Air circulation and lightening holes 54 are preferably provided in plate 51. A knob 56 is rigidly fixed to the outer end of shaft 47 by means of screw 57. When drive shaft 47 is rotated by means of knob 56, it feeds in and out of threaded boss 53 and thereby moves the tuning door 41 to any desired position.

The tuning door as shown in Figure 4 is positioned approximately at the middle of its travel. The door can be moved outwardly until its outer contact fingers 46^1 engage plate 51, and it can be moved inwardly to the position shown by dotted line 42. The limit of inward movement is fixed by the fact that when body portion 42 of the door reaches the dotted line positions, knob 56 has moved inwardly into contact with boss 53. It will be seen in Figure 4 that the limit of inward movement is such that the surface of body portion 42 is positioned adjacent the contact finger 39 on the tuning box. If body portion 42 were permitted further inward movement, its lower contact fingers 46 would tend to become entangled with fingers 39 and would lose contact with the middle portion of walls 32.

It will be understood from Figure 4 that concave shape of tuning doors 41 permits the formation of a smaller cavity resonator than could be obtained if the inner surface of each door were flat. By way of example, it was found that a specific resonant cavity which had a frequency range of 700—925 megacycles with flat type tuning doors had a range of 706—1,000 megacycles when equipped with concave doors as shown in the drawings.

It will be noted that the substitution of the concave door for a flat door increases the high frequency end of the range by seventy-five megacycles and yet changes the low frequency end by an increase of only six megacycles. It is believed that at least two reasons contribute to this desirable result. Obviously, the door 41 occupies more volume by reason of its concave shape than it would occupy if it were made flat across the bottom edges of contact fingers 46. However, this additional volume of the concave door is a much higher percentage of the effective resonator volume when the door is at its inward limit of movement than when the door is at its outward limit.

A second reason why the concave door substantially increases the high frequency end of the tuning range without appreciable effect on the low frequency end is that the effective inner surface of door 41 is believed to move outwardly on body portion 42 as the door itself is moved outwardly. In order to explain this phenomenon it is desirable first to point out that there is an air gap between each side of the tuning box and the adjacent side of the body portion 42 of the tuning door. Figure 4 shows such air gaps between body portion 42 and walls 31 of the tuning box; the same size air gap exists between the body portion and walls 32. As will be understood by those skilled in the art, the electrostatic filed within each cavity resonator is concentrated at the center of the cavity and decreases radially outwardly of the center. Thus the field is strongest within the gaps 13, 14 and 15 and is weakest at the outer ends of tuning boxes 30.

The capacitance across the gap between the tuning door body and the adjacent tuning box walls is a function of the field strength in which the door is positioned, such capacitance being high in a strong field and low in a weak field. Thus, when the door is in the inward position shown by dotted line 42, very high capacitance exists between body portion 42 and the tuning box walls. Such high capacitance of course means that radio-frequency current can flow with relative ease from the tuning box walls to the tuning door body 42. As a result the current is shorted almost directly from the tuning box walls to the edges of the inward surface of tuning door body 42, so that the inner surface of body portion 42 forms the outer end of the cavity.

However, when the tuning door is moved to its outward limit, it is positioned in a relatively weak electrostatic field, and a very low capacitance exists between body portion 42 and the tuning box walls. The existence of such low capacitance means that the current finds it difficult to flow across the gap between the cavity walls and the tuning door body 42. As a result the current passes from the cavity walls to the tuning door at an effective position radially outward of the inward surface of body portion 42. Depending on the physical dimensions and electrical values involved, some or all of the current can be shorted across the contact fingers 46 and 46^1, and the remaining current passes through the gap radially outward from the edges of the inner surface of body portion 42. Thus, as the tuning door is moved toward its outer limit, the effective outer end of the cavity tends to become coincident with the rim of contact fingers 46 and 46^1, and, as the door is moved toward its inner limit, the effective outer end of the cavity tends to become coincident with the inner surface of body portion 42.

Referring again to Figure 4, it will be seen

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COMPLETE SPECIFICATION
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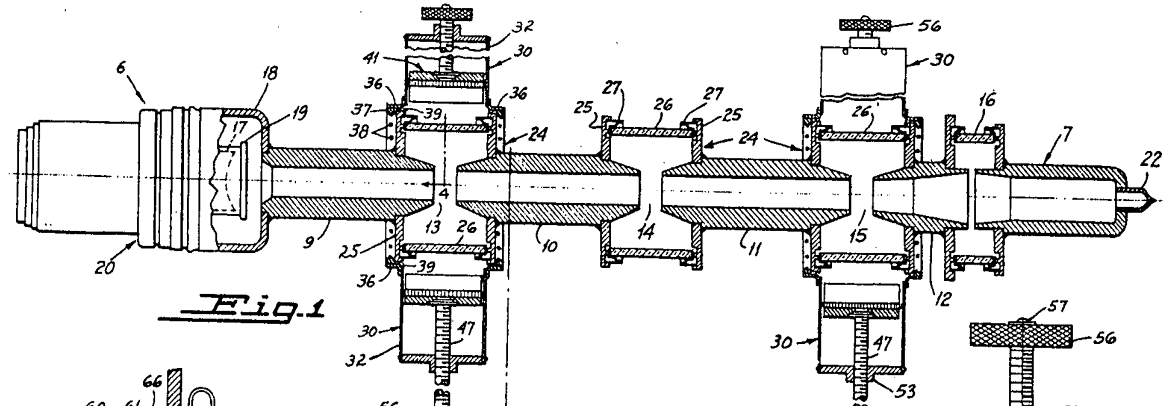

Fig.1

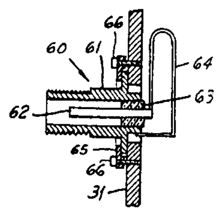

Fig.5

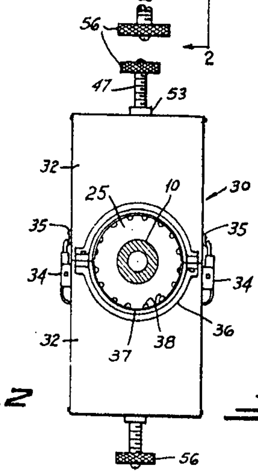

Fig.2

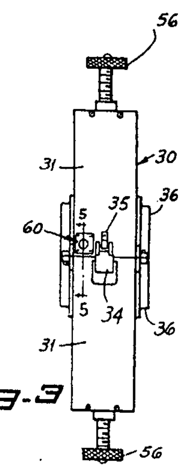

Fig.3

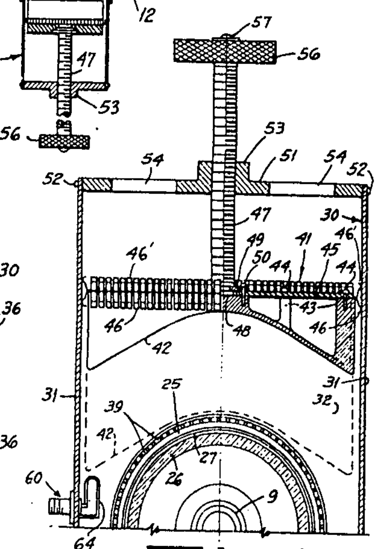

Fig.4